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GLOBAL INTERCONNECTIVITY BETWEEN MOBILE SATELLITE AND TERRESTRIAL USERS: CALL SIGNALING ISSUES AND CHALLENGES

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Abstract. This paper will discuss some of the challenges in connecting mobile satellite users and mobile terrestrial users in a cost efficient manner and with a grade of service comparable to that of satellite to fixed user calls. Issues arising from the translation between the mobility management protocols resident at the satellite earth station and those resident at cellular switches - either GSM (Group{ "Special Mobile) or 1S-41 (used by U.S. digital cellular, systems) type - will be discussed. The impact of GSM call routing procedures on the call setup of a satellite to roaming GSM user will be described. Challenges facing provision of seamless call handoff between satellite and cellular systems will be given. A summary of the issues explored in the paper are listed and future work outlined.

INTRODUCTION

In the next ten years, a plethora of persona] communication devices will become available for use at work and at home. Some will offer low data rate simplex services, such as paging or database downloading; others will offer higher data rate duplex services, such as telephony, FAX, data communications, and perhaps image and video transmission. Many of the systems providing higher data rate duplex systems wish to provide their customers with "anywhere, anytime" access to "anybody". In the personal communication systems area alone, there are a wide variety of products ranging from cordless telephony for the home (using CT-2 and DECT

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standards), to analog (AMPS) and digital cellular (1S 54, IS 95 in the U.S. and GSM in Europe), to Personal Communication Systems (PCS), to mobile satellite systems (such as Globalstar, IRIDIUM, Odyssey, ICO . ..). interconnecting these diverse systems in a low cost fashion with a reasonable grade of service creates challenging and important problems - solutions for which being explored by terrestrial and satellite system providers alike.

This paper discusses some of the signaling and mobility management issues which exist in providing communications between mobile satellite users and mobile terrestrial users in a cost efficient manner and with a grade of service comparable to that of satellite to fixed user calls. We categorize these issues according to whether they related to the efficient allocation of ground- and space-based networks during the setup of a call or the reallocation of ground- and space-based networks during the course of a call. We propose possible solutions and discuss future areas of work.

SATELLITE GATEWAY REFERENCE MODEL

The generic satellite gateway reference model, depicted in Fig. 1, is useful in understanding how mobile satellite systems will interconnect with the terrestrial Public Switched Telephony Network (PSTN), with the Integrated Services Digital Network (ISDN) and with terrestrial mobile (cellular and PCS) networks [1]. This satellite gateway reference model is based the PCS reference model proposed by the Telecommunication industry Association (TIA) Engineering Committee TR-46 Mobile and Personal Communications. As will be subsequently seen, the TR-46 model differs slightly from the GSM model used by European digital cellular systems. However, its implementation differs greatly between systems in respect to both the interface definition and the mobility management protocols used.

As seen in Figure 1, the satellite links the Wireless Personal Terminals (WPT_0 to WPT_2) to the satellite gateway. The satellite gateway is shown as supporting independent interfaces to the Public Switched Telephone Network (PSTN) through the Ai interface, to the integrated Services Digital Network (ISDN) through the D interface, and to terrrestrial Mobile Switching Centers (MSCs) via the E interface,

The radio components includes the Air Interface (Urn) and the Base Station System (BSS). The Um interface specifies the physical layer and access methods as well as the traffic and control link protocols. The BSS includes the Base Transceiver Station (BTS) and the Base Station Controller (BSC) subsystems. The network components includes the MSC. and its interconnection to its Home and Visitor Location Registers (HLR/VLR) via the C and B interfaces and to its Equipment Identity Register (EIR) via the F interface and to the Authentication Center (AC) via the HLR.

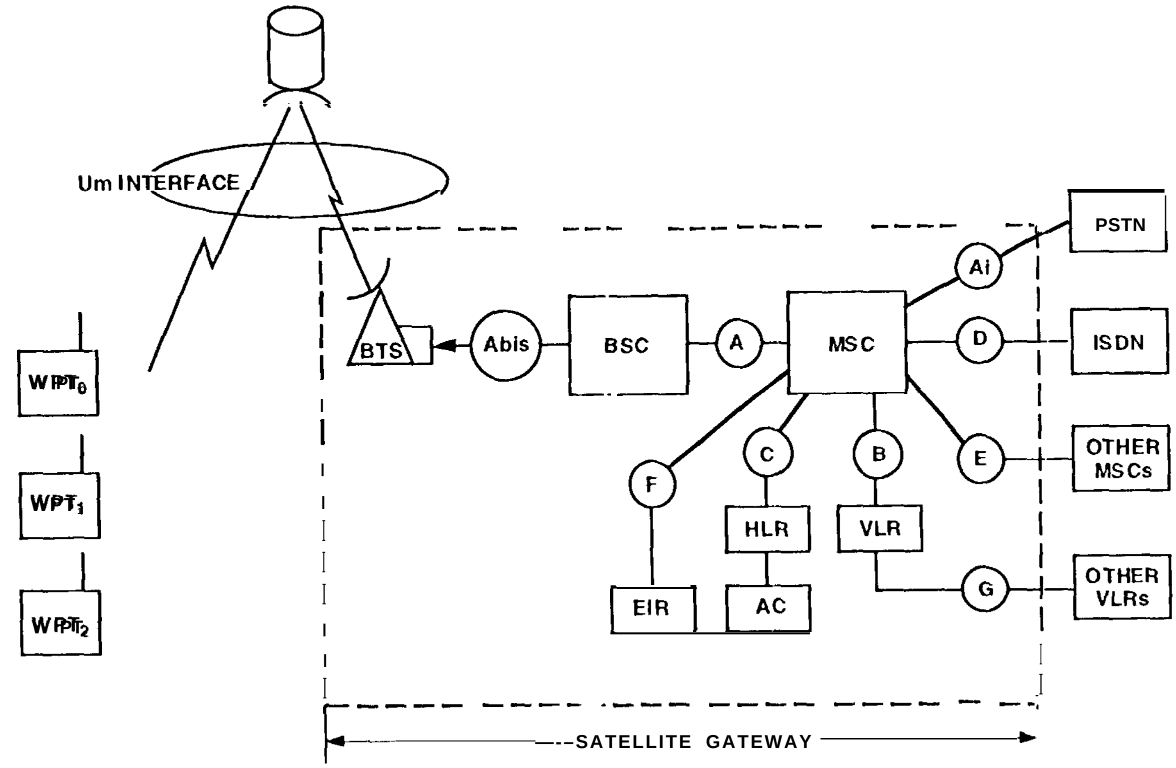

Figure 1. Satellite gateway reference model.

The IS-41 protocol governs messages sent over these interfaces and was designed specifically to permit seamless roaming between calling areas in the U.S. The IS-41 protocol relies on various parts of the SS7 protocol upon which the Intelligent Network is based [2]. Specifically IS-41 relies on the Transaction Capabilities Application Part (TCAP) and the Signaling Connection Control Part (SCCP) to communicate with databases (such as HLRs and VLRs) and other network entities (such as EIRs and ACs). The ISDN User Part (ISUP) and Message Transfer Part (MTP) protocols of the SS7 protocol stack are used by IS-41 to connect mobile calls to the PSTN, and to connect mobile circuits from the MSC to the BSS.

The European digital cellular (or GSM) network model is shown for reference in Figure 2 [3]. The OMC refers to the Operations and Maintenance Center and the AUC refers to the Authentication Center. In the European system, the Mobile Application Part (MAP) protocols have been designed to handle mobility management issues. They are listed by their conventional letter reference beside the interface to which they apply and follow very closely the nomenclature for the IS-41 protocol used in the U.S.

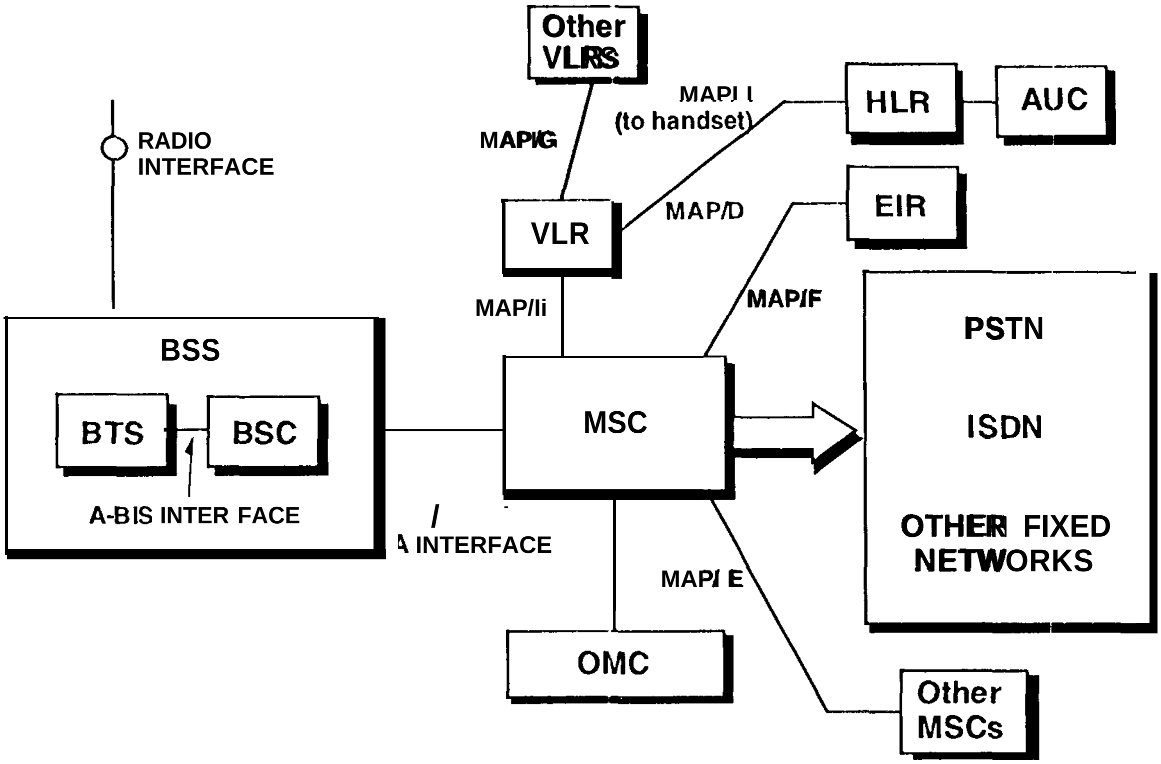

Figure 2. GSM network model.

The MAP protocols are subdivided according to different application areas into MAP/B, MAP/C, up to MAP/1, All of the MAP protocols use the services provided by the SS7 protocol TCAP (the Transactions Capabilities Application Part). The various MAP protocols have the following functions.

MAP/B provides for communication between the MSC at the user end and its associated VLR.

MAP/C is the protocol between a GMSC (Gateway MSC) and an HLR. It allows the GMSC to get routing information for incoming call establishment. Representative messages defined in this protocol are: Alert Service Center, Send Routing Info for Short Message, Send Routing information, Set Message Waiting Data, Register Charging Information.

MAP/D is the protocol between a MSC/VLR and an HLR. This is mainly a protocol for mobility management. Representative messages are: Activate Trace Mode, Cancel Location, Deactivate Trace Mode, Delete Subscriber Data, Reregister Mobile Subscriber, Insert Subscriber Data, Note Mobile Subscriber Present, Provide Roaming Number, Reset, Send Parameters, Update Location.

When a call undergoes a handover to another MSC /VLR, the entry point of the call is not changed; it is designated as the *anchor* MSC. The other MSC in charge of the new cell where the mobile station is located is called the *relay* MSC. The protocol between the anchor MSC and the relay MSC is the MAP/ii. Typical messages are: Forward access signaling, Note internal handover, Perform handover, Perform subsequent handover, I'recess access signaling, Send end signal, Trace subscriber activity.

The MAP/F protocol is between the equipment identity register (EIR) and the MSC/VLR. It consists of the single message Check IMEI (International Mobile Equipment Identity). The MAP/G protocol plays a minor role in user identity protection. identity protection may be obtained by providing a user with a temporary mobile subscriber identity (TMSI) which is used to establish a connection prior to entering into encrypted transmission. During the process of establishing the connection, the mobile terminal provides the MSC/VLR responsible for initially setting up the TMSI (rather than the HLR or even the home PSTN). This MSC/VLR has information about the subscriber (the International Mobile Subscriber Identit y, or IMSI). The protocol for requesting this information from the MSC/VLR is the MAP/G protocol with only two messages: Send Parameters and Send Parameters Result.

MAP/H is the protocol between the Short Message Service gateway (SMS-gateway) and the MSC/VLR. Supplementary services include capabilities such as call forwarding, call waiting, or call hold. Activating or de-activating these features is done by the mobile terminal, and the information is stored in the HLR. It is not shown in Figure 2.

The MAP/I protocol is the protocol between the mobile terminal and the HLR that carries the signaling pertaining to these supplementary services. Messages in the protocol include (where SS means supplementary services): Activate SS, Deactivate SS, Erase SS, Forward Check SS Indication, Forward SS Notification, Get Password, invoke SS, Process Unstructured S S Data, Register Password, Register SS.

The interface between the BSC and the MSC/VLR (the A interface) is established using the SCCP protocol, which is an SS7 protocol. The SCCP has several classes of service, including a basic connectionless mode (class 0) and a connection-oriented mode (class 2). The class O mode is used on the A interface for messages not directly related to a single mobile station. The class 2 mode is used for separate independent connections (signals from a mobile station to the MSC/VLR and back).

Comparison of the interfaces shown in Fig. 1 (based on the U.S. Mobile and Personal Communications standards) and in Fig. 2 (based on the European digital cellular standard) show minor differences in the reference models primarily relating to the relationship between the MSC and HLR. Major differences relate to the definition of the interfaces and to the mobility management protocols used (IS-41 vs. MAP).

COMPARAISON BETWEEN IMPLEMENTATION OF CURRENT SATELLITE SYSTEMS AND THE GATEWAY REFERENCE MODEL

According to papers published recently, most of the first generation satellite systems will not implement all of the interfaces shown in Figure 1 **[4,5]** due to the cost and the limited use of these interfaces at service inception, It appears that most gateways will support the Ai interface with a possibility of setting up E interfaces to the MSCs within the satellite gateway footprint.

ROLE OF THE INTELLIGENT NETWORK

As stated above, the intelligent Network and the SS7 protocol stack upon which it is based provide the basis for the IS-41 and MAP protocols. Each nation has its own national variant of SS7 which is translated at national boundaries into an international SS7. Therefore there are two network levels in SS7. The lower level is used to build networks on a national level; it is based upon the MTP networking protocol. The other level is used for interconnecting all of the national networks. Corresponding with the two levels of networks are two levels of addressing. The MTP code only hold relevance within a limited scope, such as in one national SS7 network. The MTP protocols suffice to route messages of this sort. on the other level, there is a “global title,” by which any SS7 point in the world may be addressed.

CALL, SIGNALING ISSUES AND CHALLENGES

In this paper call signaling refers to the messages that flow between the various parts of the satellite and terrestrial network in order to link the mobile satellite user to the terrestrial user. Some of these messages may be related to verifying that the caller and their equipment are legitimate users of the network and some may relate to locating the called party. Others are required to set-up the connections between the satellite network and other networks. As more diverse networks become interconnected, call signaling issues become more complex and challenges to providing rapid call set-up and low cost calls arise.

It is commonly believed that the dominant traffic for first generation mobile satellite systems will be telephony between mobile satellite users and users with fixed (non-mobile) telephone sets. This scenario is depicted in Figure 3.

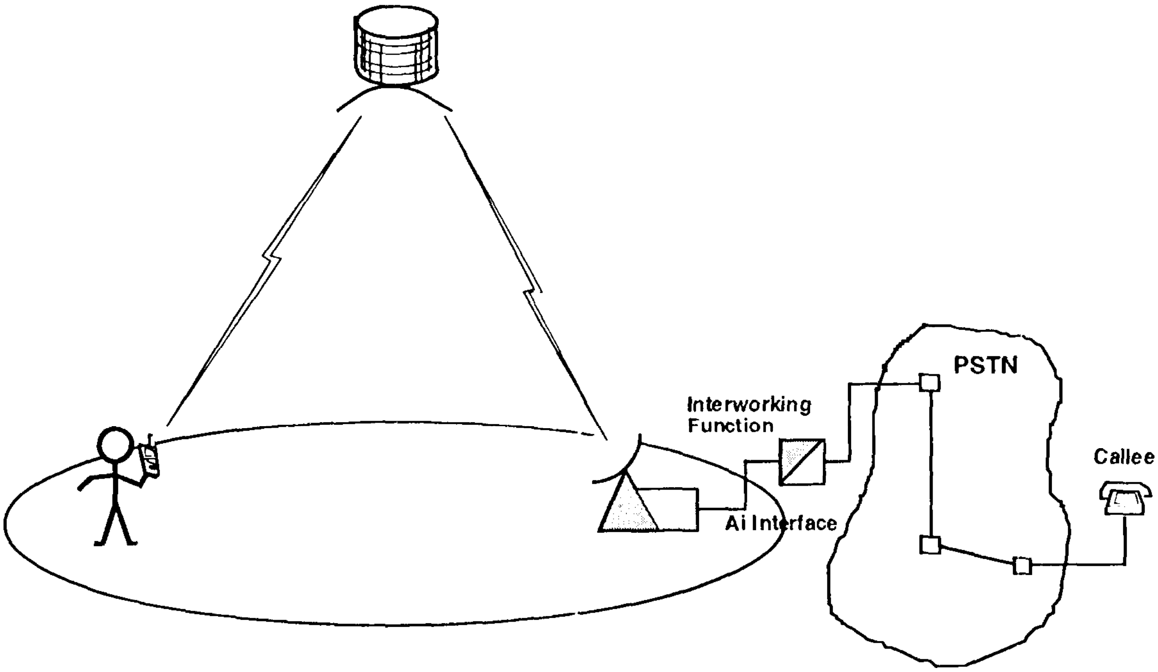

Figure 3. Mobile satellite user to fixed user call set-up.

The function of the satellite gateway will be to route the call from the MSC to the PSTN via the Ai interface. The satellite gateway maybe using IS-41 or GSM based protocols based on a national variant of SS7 that may not be compatible with the type of SS7 that is locally used. Translation between the TSUP, SSCP, TCAP, and MTP protocols used within the gateway to those in the local PSTN will be carried out by an internetworking function component which is depicted in the figure as translating for a particular shade pattern to a clear pattern. As satellite gateways will be located on a variety of countries depending on the particular mobile satellite system, there could be a number of SS7 protocol translation boxes necessary.

As more personal telephony and data communications devices become available, the number of calls between mobile satellite users and mobile terrestrial users will increase. Call set- up issues such as timely location of the called party and efficient call routing will become important in order to maintain the Grade of Service (GOS) expected by the user and to minimize the call cost. in addition the existence of more sophisticated networks capable of reevaluating the partition of network resources assigned to a particular call at call set-up will permit reassignment of network resources mid-call. Efficient allocation of network resources at call set-up and efficient reallocation of network resources mid-call are the two main challenges to global interconnectivity discussed in this paper.

Call Set-Up Signaling Issues and Challenges

Let us examine some of the mobility management and call set-up related issues that arise when a mobile satellite user is calling a terrestrial mobile user. Figures 4 and 5 depicts the case of Nina, currently in Asia but a registered user in the U. S., calling Mark, a cellular user, who can be at home in the Netherlands or roaming in South America. Figure 4 assumes that the satellite system is one which tries to utilize terrestrial network as much as possible whereas in Figure 5 use of the satellite network (which possess Inter - Satellite Links) is maximized. in the figure, the satellite gateways utilize a specific type of mobility management protocols (some variant of IS-41 or MAP running on a particular variant of SS7; these are shown in light gray). Each of the four continents utilizes a different variant of SS7 (unlike that of the satellite system). Thus there are five types of SS7 that must be converted between. In addition Mark's cellular system uses a different type of mobility management protocols than the satellite system.

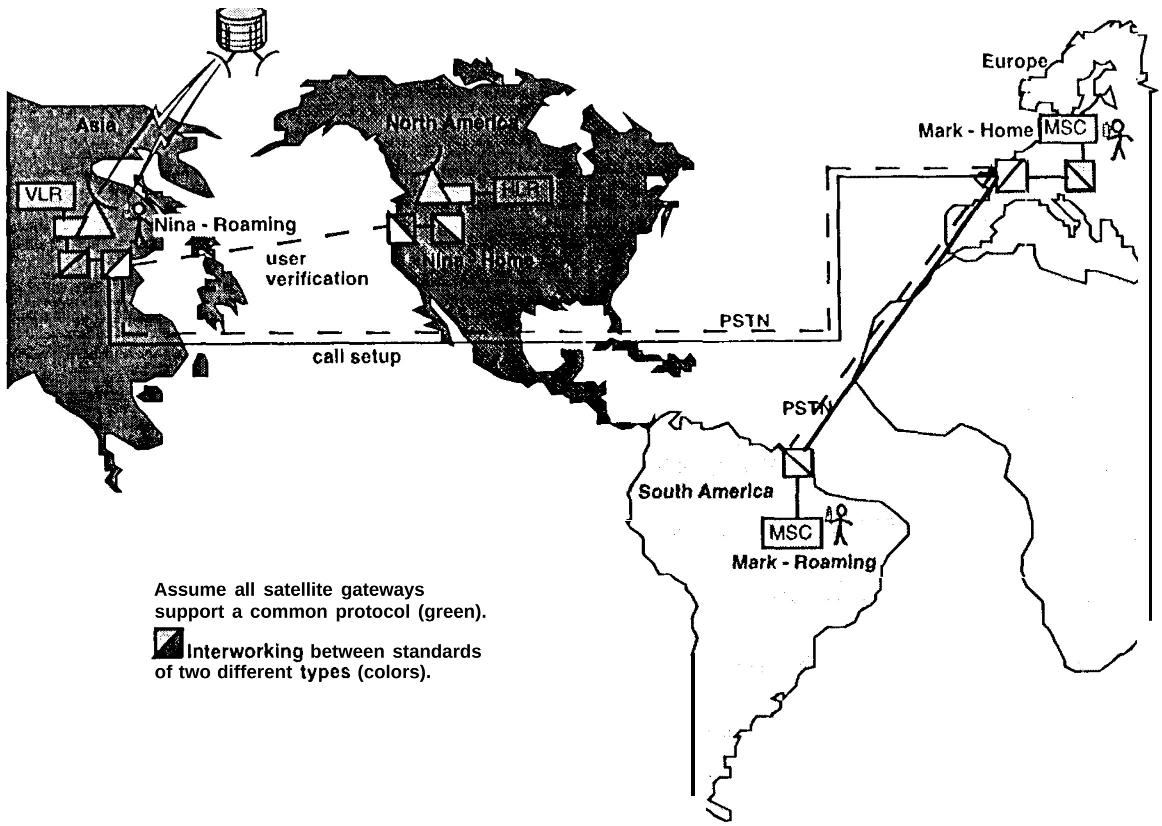

Figure 4. Mobile satellite user (on non-ISL satellite system) to mobile terrestrial user call up.

A typical call might proceed as follows. When Nina picks up her satellite handset to place the call, she is authenticated as a paying customer in good standing (through her home AC) and her equipment's ID is checked (through her home EIR) by communications (either over a satellite or a terrestrial connection) between her "visiting" gateway in Asia and her "home" gateway in the U.S. Protocol translation takes place so that the two satellite gateways can exchange information.

Mark's phone number identifies him as a GSM user. The gateway MSC in his country is queried in order to find the appropriate HLR. The HLR, being a database, provides Mark's identity and the information for muting to Mark's home MSC. The home MSC queries its VLR to see if Mark is currently there or in another location, The ISUP protocol (Initial Address Message) governs this series of transactions and can time out if receipt of Mark's final number takes longer than anticipated. One can easily imagine if Mark is not at home but is roaming, then the ISUP protocol may timeout. One possible solution is for Mark's home MSC to respond to the query by Nina's satellite gateway with a premature response, this is an inelegant but practical solution.

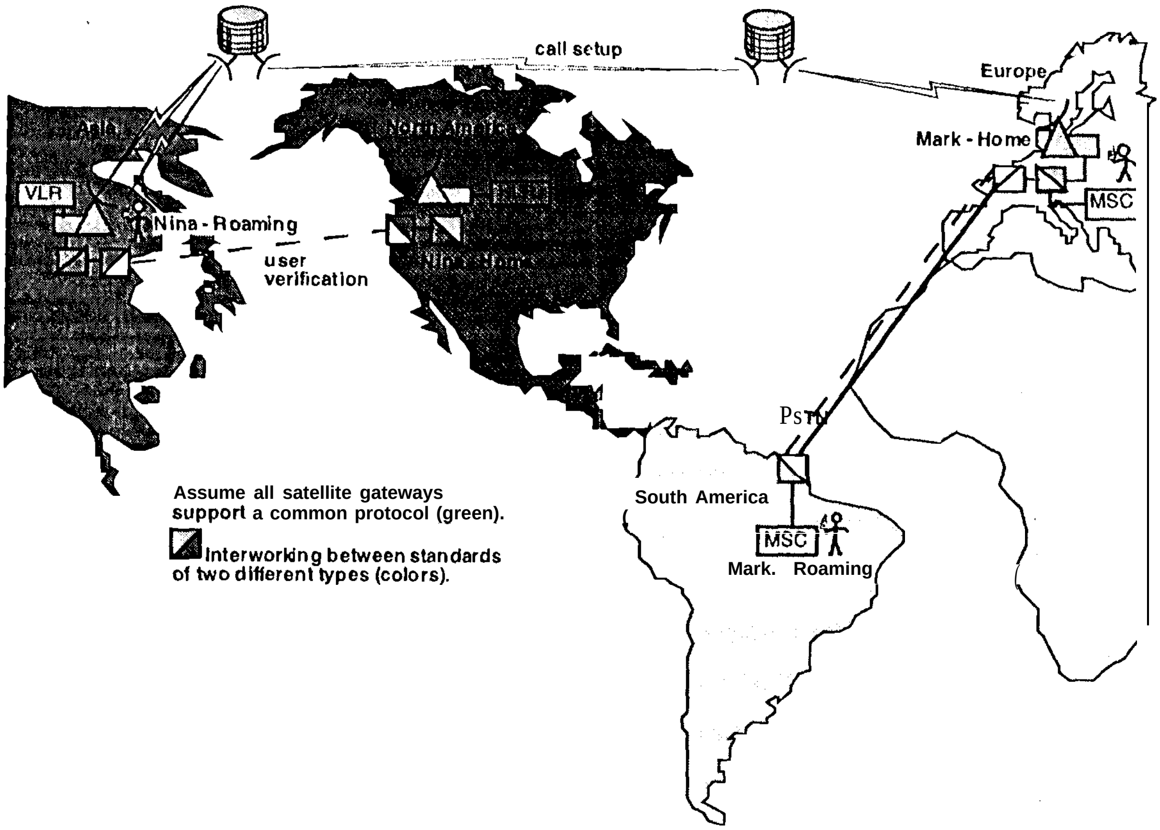

Figure 5. Mobile satellite user (on ISL satellite system) to mobile terrestrial user call up.

A second issue arises when Mark is roaming. As currently set-up, the GSM system requires the messages (for call setup and subsequent user data) to be routed through the home MSC: this produces the so-called "tromboning" effect which can lead to a very costly call. This solution was chosen by the GSM system implementers for billing and call privacy purposes but may be very disadvantageous for satellite users who already have high call costs.

Figure 5 illustrates the same scenario as in Figure 4 with the exception that the mobile satellite system now possesses 1S1, between satellites. This capability increases the value of supporting an E interface between the gateway and the terrestrial mobile user's MSC. In addition the additional cost of tromboning could possibly have been offset through use of the appropriate satellite resources.

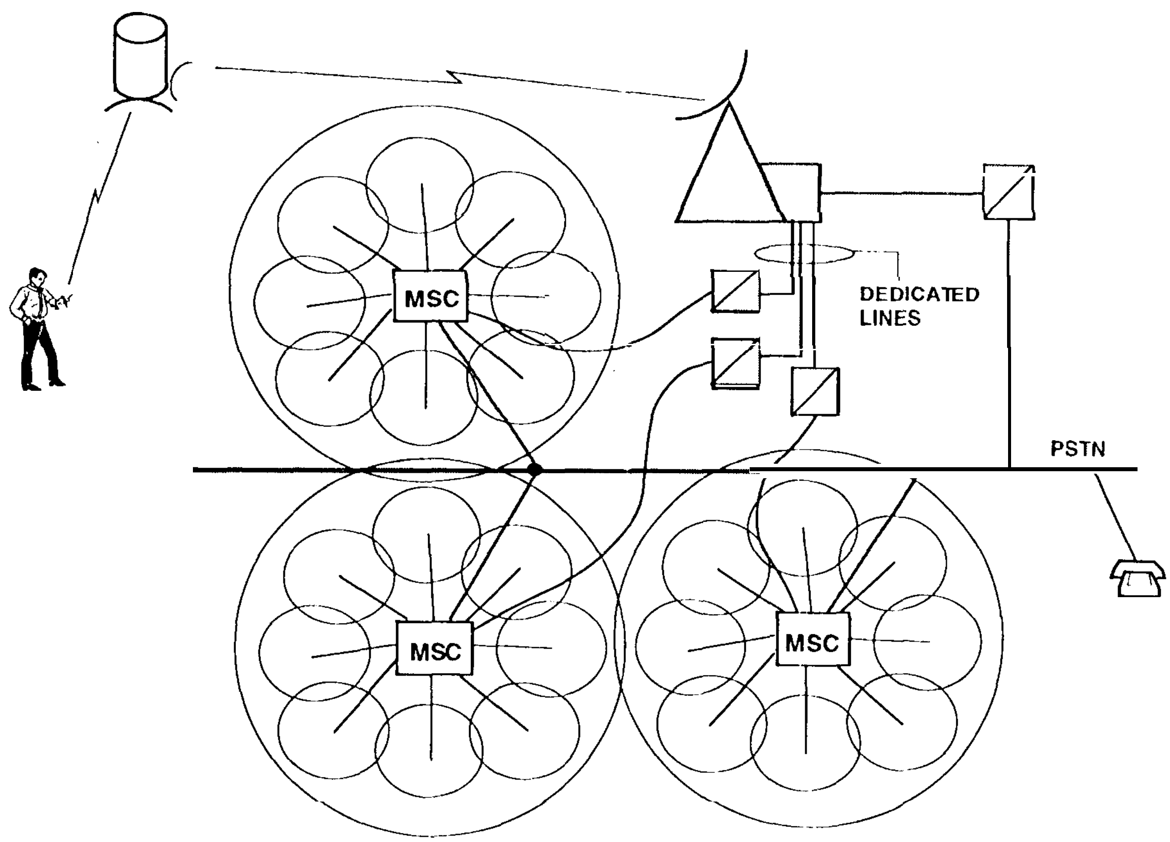

Figure 6. Satellite gateway with E interfaces to surrounding terrestrial mobile systems can support users with dual-mode handset who move into terrestrial coverage area mid-call.

Reallocation of Network Resources Mid-Call: Signaling Issues and Challenges

Personal or vehicular user roams from satellite to terrestrial coverage during a call. User possesses a dual-mode handset. Call handoff is desirable to ensure continuous coverage at best GOS, efficient use of satellite resources and cost efficiency, however this requires the satellite gateway is establish E interfaces with specific MSC within the satellite's footprint. This scenario is "displayed in Figure **6.**

SUMMARY

Call Set-up Issues

Examination of these issues for satellite users to fixed users brought out that the proliferation of different variants of mobility management protocols and **SS7** types translate into a need for protocol conversion boxes from one standard to another.

Examination of these issues for satellite users to mobile users brought out two additional issues related to the timely location of the user (prior to timeout of ISUP protocol) and cost effective routing (without tromboning).

Examination of these issues brought out the possible benefit of setting up the need for an E interface between the satellite gateway and the surrounding cellular system MSCS to accommodate call between satellite user and terrestrial mobile user in gateway's footprint. Another benefit for mobile satellite systems with ISL is to permit delivery of calls from gateway nearest callee directly to caller without entering PSTN.

Reallocation of Network Resources Mid-Call: Signaling Issues and Challenges

Examination of **these issues** points to benefit of supporting call handoff between the satellite system and the terrestrial system through the implementation of the E interface.

CONCLUSION

As more personal telephony and data communications devices become available, the number of calls between mobile satellite users and mobile terrestrial users will increase. Call set-up issues such as timely location of the called party and efficient call routing will become important in order to maintain the Grade of Service (GOS) expected by the user and to minimize the call cost. In addition the existence of more sophisticated networks capable of reevaluating the partition of network resources assigned to a particular call at call setup will permit reassignment of network resources mid-call.

Examination of specific issues regarding the efficient allocation of network resources at call set-up and efficient reallocation of network resources mid-call has led to the identification of protocols which could be modified to improve the effectiveness of interconnecting satellite and terrestrial mobile users. Future work will identify the specific changes to existing signaling standards and to quantify the improvement realized by implementing the proposed changes.

ACKNOWLEDGMENT

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